No-boundary measure and preference for large e-foldings in multi-field inflation

Soo A Kim
Asia Pacific Center for Theoretical Physics

Based on arXiv:1207.0359 by

Dong-Il Hwang, SAK, Bum-Hoon Lee,
Hanno Sahlmann(Erlangen-NUmberg)
and Dong-Han Yeom (CQUeST)

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Outline

- What is no-boundary measure?
- Motivations
- No-boundary measure with multi-field inflation
- Conclusions (and future work)

What is no-boundary??

Hartle–Hawking state

From Wikipedia, the free encyclopedia

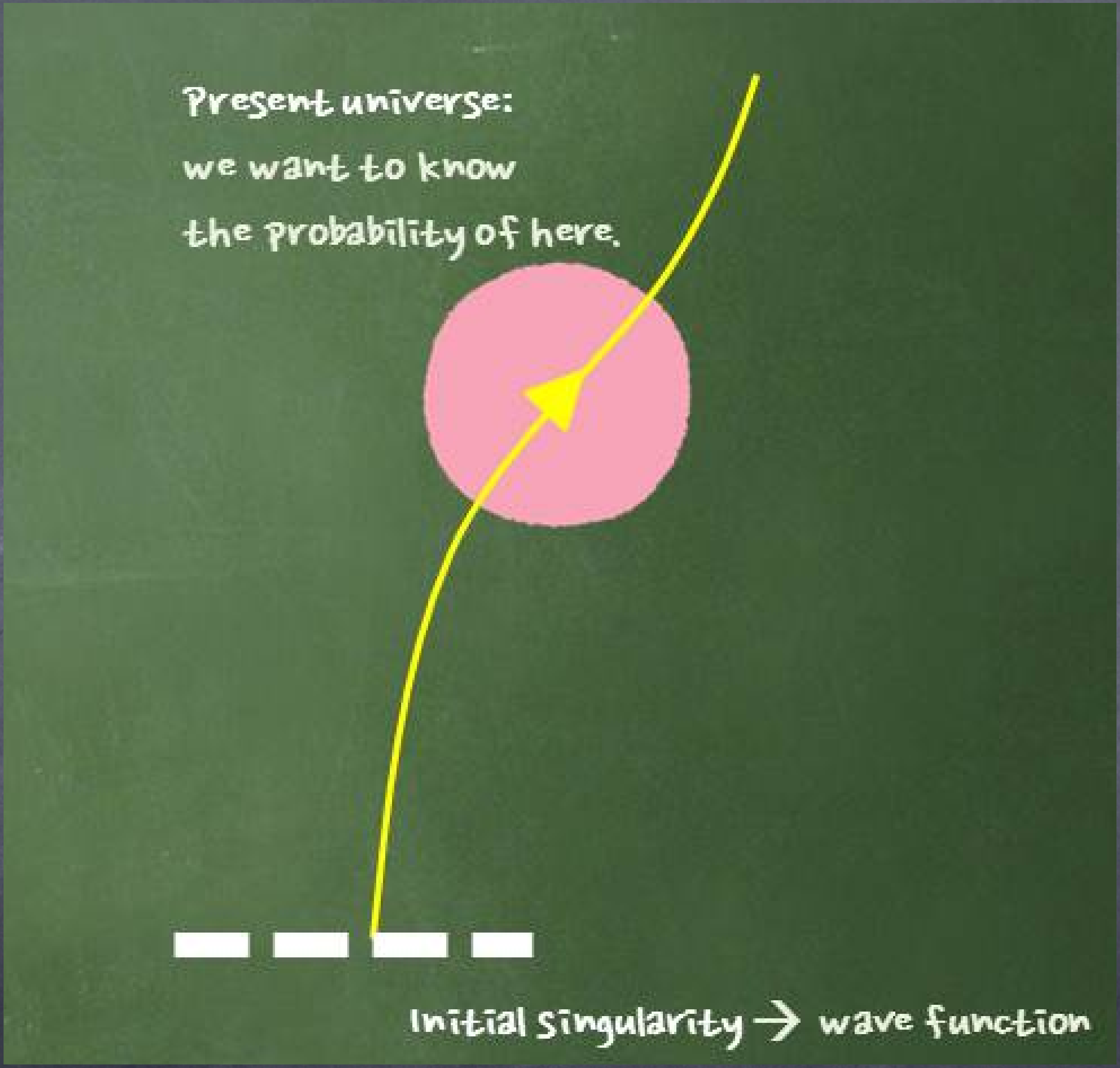
The Hartle-Hawking state is a proposal concerning the state of the universe prior to the Planck epoch. Hartle-Hawking is essentially a no-boundary proposal that the universe is infinitely finite: that there was no time before the Big Bang because time did not exist before the formation of spacetime associated with the Big Bang and subsequent expansion of the universe in space and time.

James Hartle and Stephen Hawking suggest that if we could travel backward in time toward the beginning of the universe, we would note that quite near what might have otherwise been the beginning, time gives way to space such that at first there is only space and no time. Beginnings are entities that have to do with time; because time did not exist before the Big Bang, the concept of a beginning of the universe is meaningless. According to the Hartle-Hawking proposal, the universe has no origin as we would understand it: the universe was a singularity in both space and time, pre-Big Bang. Thus, the Hartle-Hawking state universe has no beginning, but it is not the steady state universe of Hoyle; it simply has no initial boundaries in time nor space.

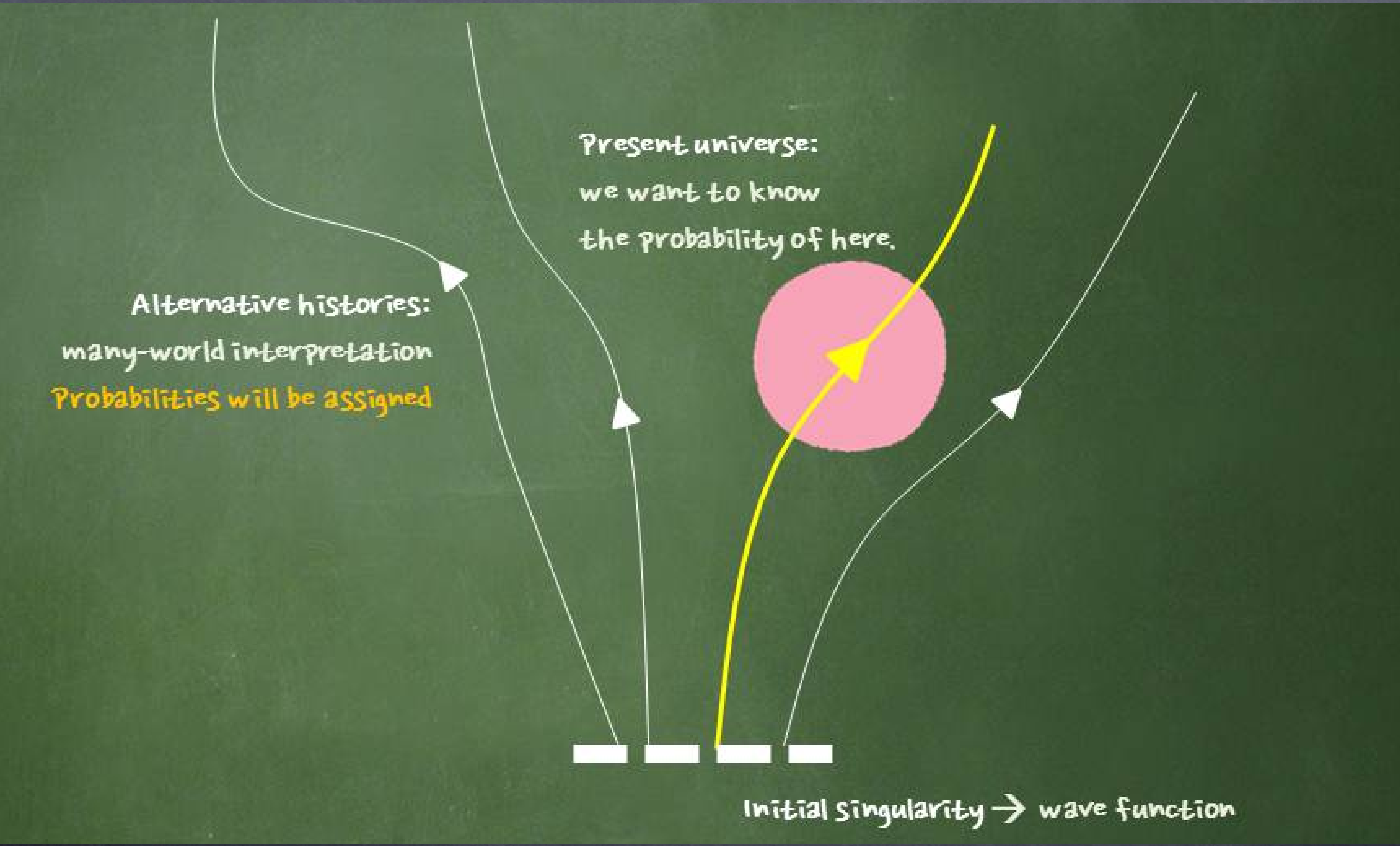
What is no-boundary?

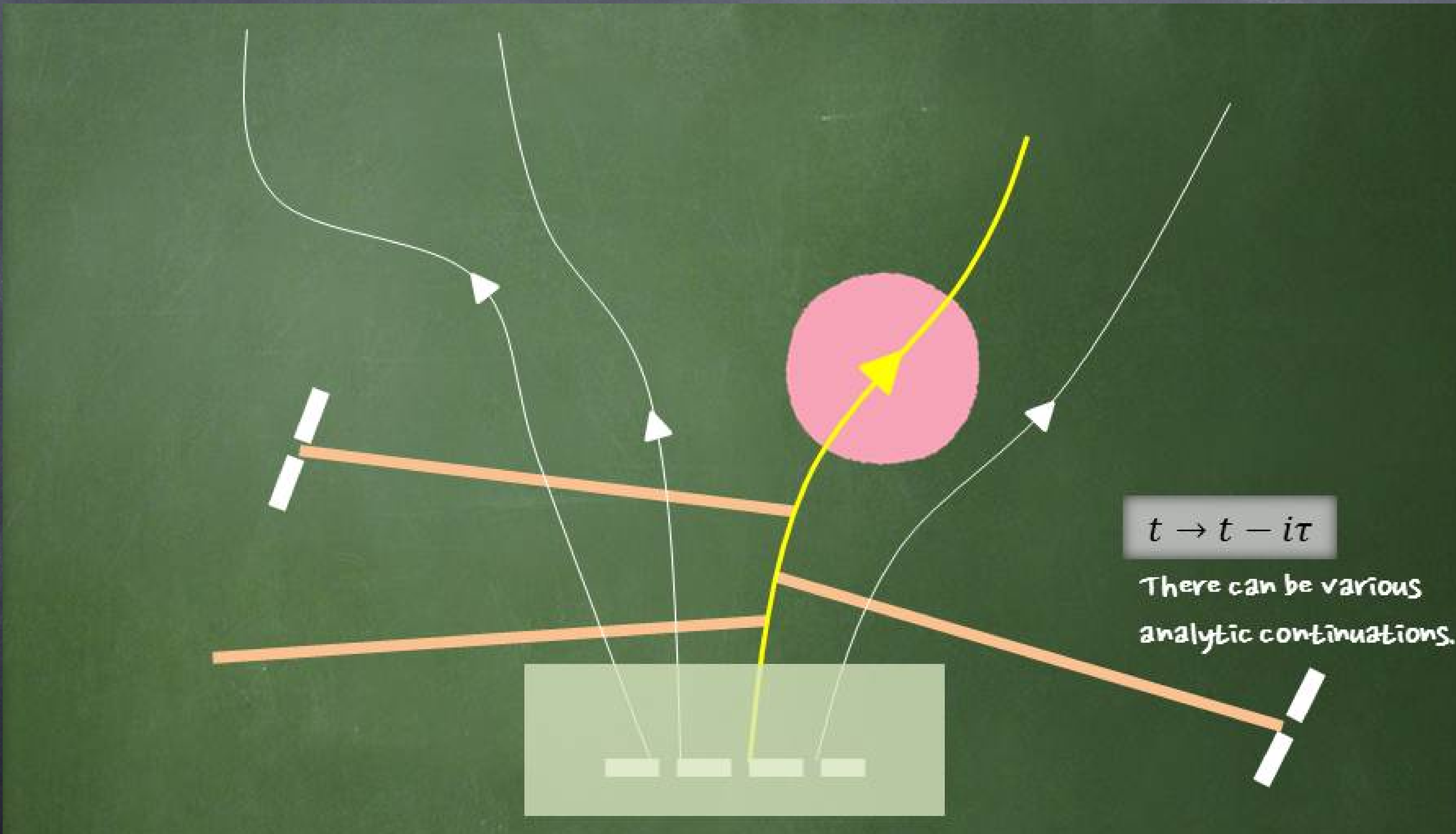
- The nature of the initial singularity of our universe??
- To canonically quantize the universe and study the wave fct of the universe as a soln of Wheeler-DeWitt equation. B.S. DeWitt, Phys. Rev. 160, 1113 (1967).

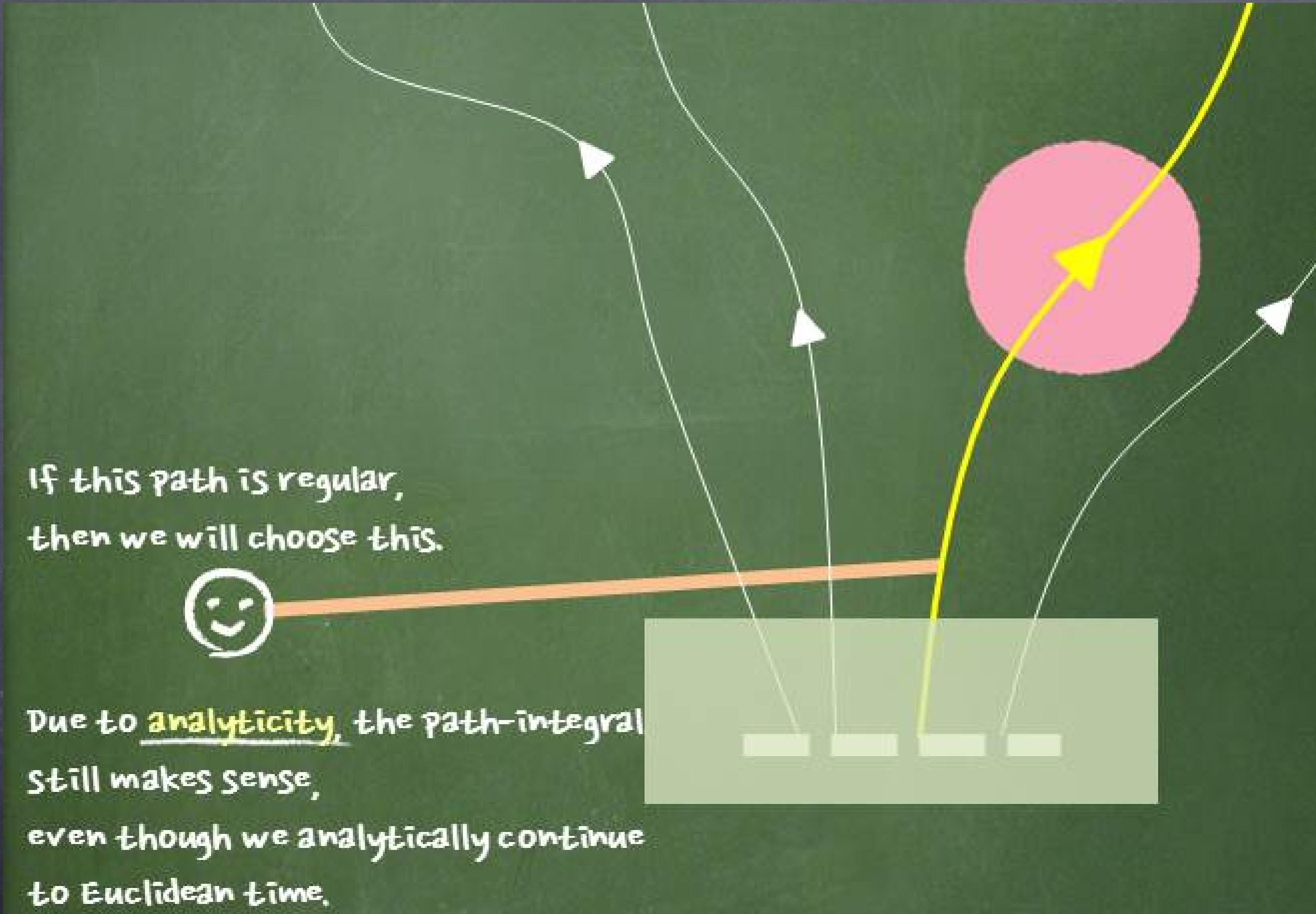
  depends on boundary condition (BC).
- The ground state can be an appealing choice.
- Hartle and Hawking suggested the Euclidean path integral as the BC of our universe, a soln of the WDW eq. J.B. Hartle and S. W. Hawking, PRD 28, 2960 (1983).

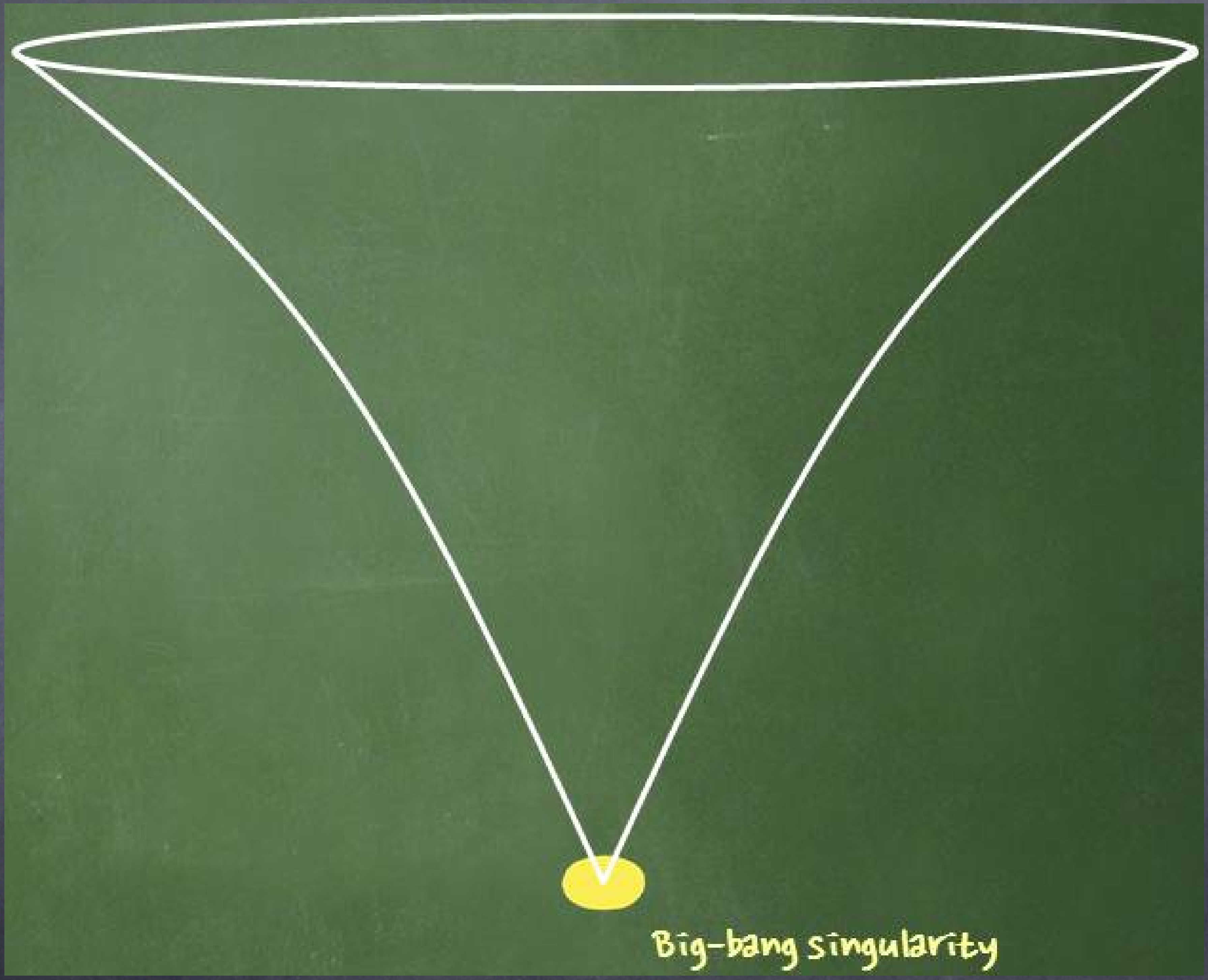


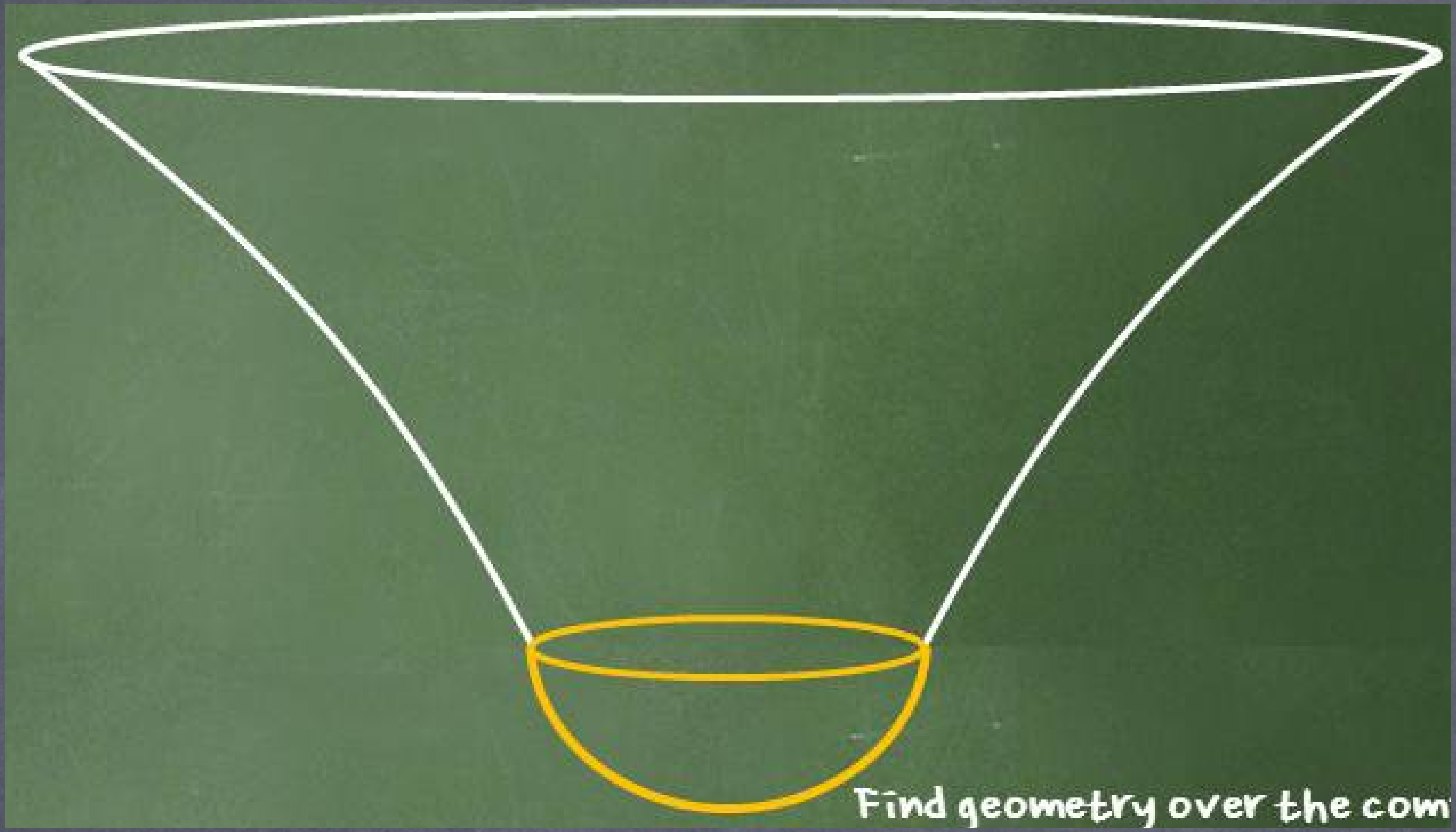
From Dong-Han Yeom's talk


Present universe:
we want to know
the probability of here.
Alternative histories:
many-world interpretation
Probabilities will be assigned
Initial singularity → wave function


$t \to t - i\tau$
There can be various
analytic continuations.


If this path is regular,
then we will choose this.
Due to analyticity, the path-integral
still makes sense,
even though we analytically continue
to Euclidean time.


Big-bang singularity

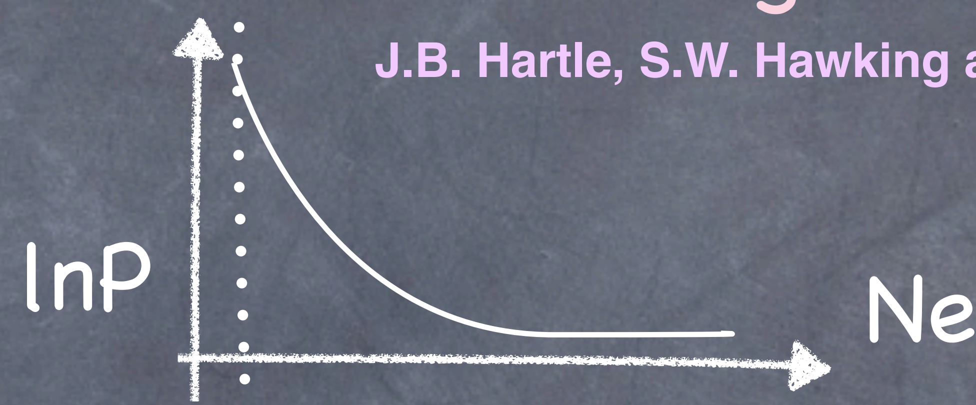


Find geometry over the complex time,
until the geometry to be regular.
Then believe the action!

Motivation I

- The no-boundary measure disfavors the histories which have a large number of e-foldings.

J.B. Hartle, S.W. Hawking and T. Hertog, PRD77, 123537 (2008), arXiv:0803.1663 [hep-th].



$$P[N_e] \propto \exp\left(\frac{3\pi}{2}\frac{1}{m^2 N_e}\right)$$

- If more than 60 e-foldings from inflation, the no-boundary measure is not compatible with this.
  - Alternatives of inflation
  - Eternal inflation and multiverse

Motivation II

- Lifting up the inflationary probabilities by ..
  - e.g. the volume weighting

$$P[N_e] \propto \exp\left(\frac{3\pi}{2}\frac{1}{m^2 N_e} + 3N_e\right)$$

S.W. Hawking and T. Hertog, PRD 66, 123509 (2002) [hep-th/024212], PRD 73, 123527 (2006) [hep-th/0602091].

- the large number of fields (eg. N-flation)??

$P[N_e]$ = ??

N-flation models

Dimopoulos, Kachru, McGreevy and Wacker, JCAP 0808, 003(2008),
Easther and McAllister, JACP 0605, 018 (2006).

- One motivation for this idea is that sufficient inflation can be obtained with all fields maintaining **sub-Planckian** values (cutoff).

- Another is that it may be possible to relate assisted inflation to proper fundamental physics models.

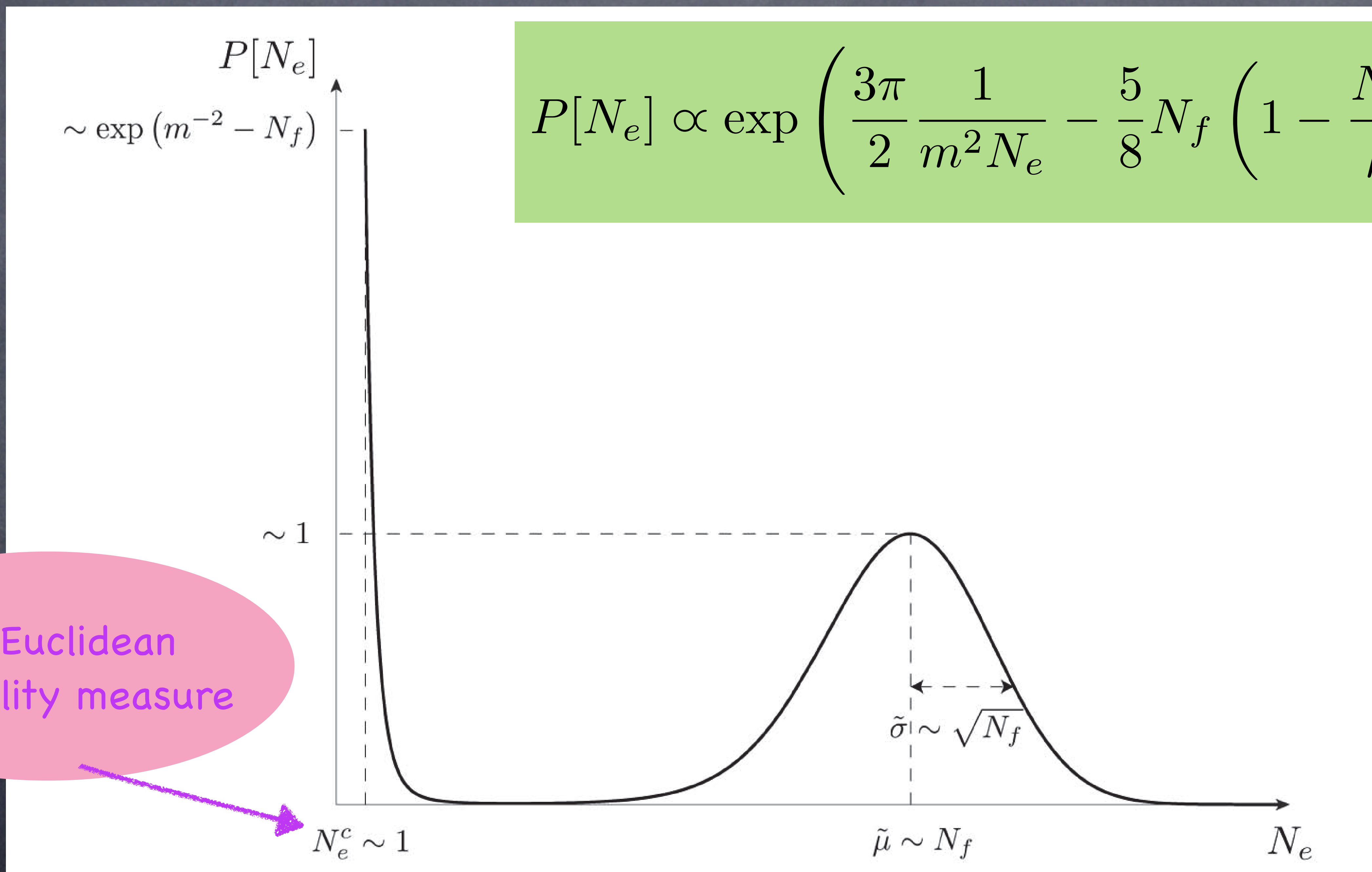
- **Random** initial conditions for fields.

SAK and Liddle PRD74, 023513, 063522 (2006), PRD76, 063515(2007),
SAK, Liddle and Seery PRL105, 181302(2010), PRD85, 023532(2012).

- Quadratic potentials, same masses.

Probability of the number of e-foldings

$$P[N_e] \propto \exp\left(\frac{3\pi}{2}\frac{1}{m^2 N_e} - \frac{5}{8}N_f\left(1 - \frac{N_e}{\tilde{\mu}}\right)^2\right)$$



the Euclidean
probability measure

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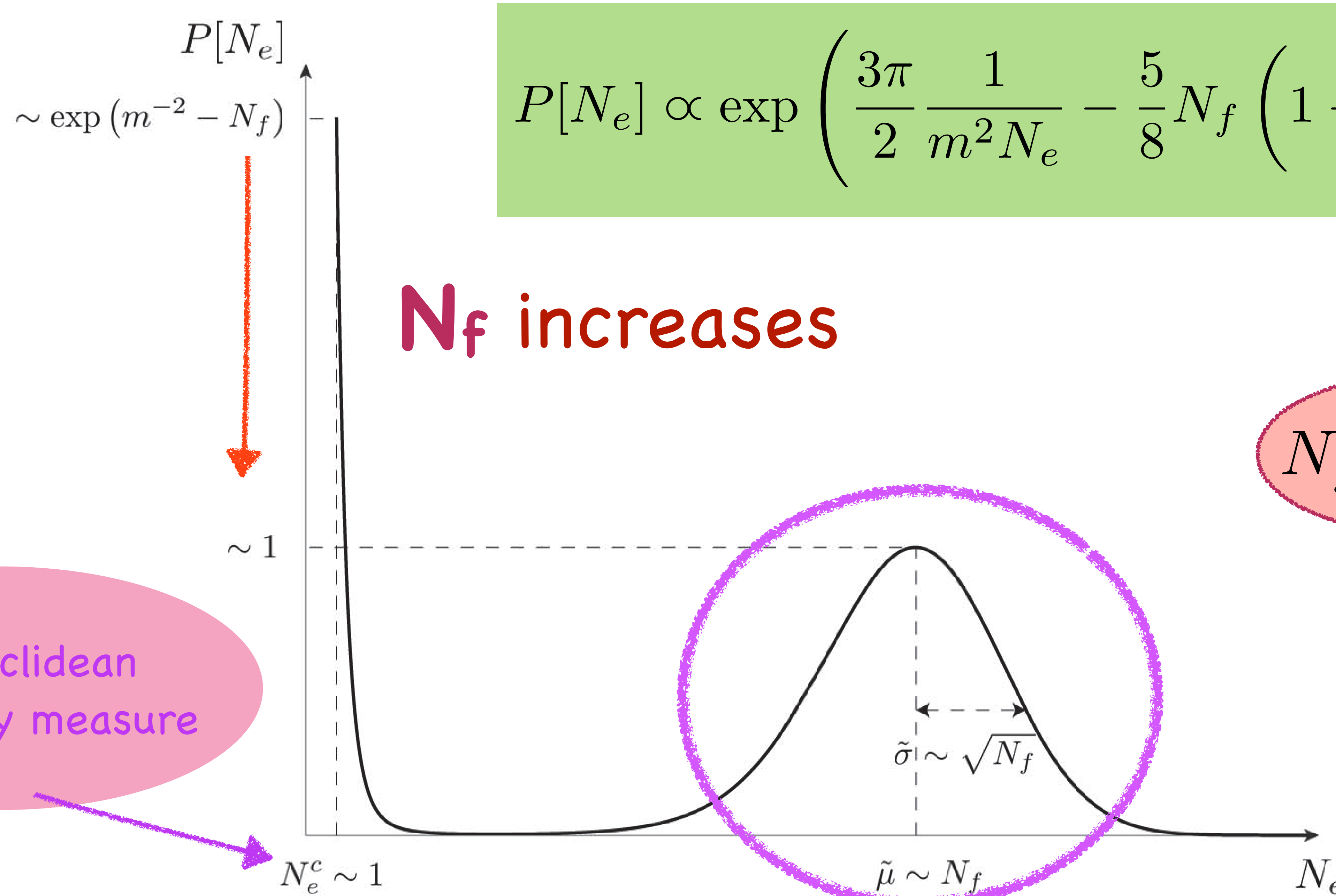

N_f increases

$N_f \gtrsim m^{-2}$

the Euclidean probability measure

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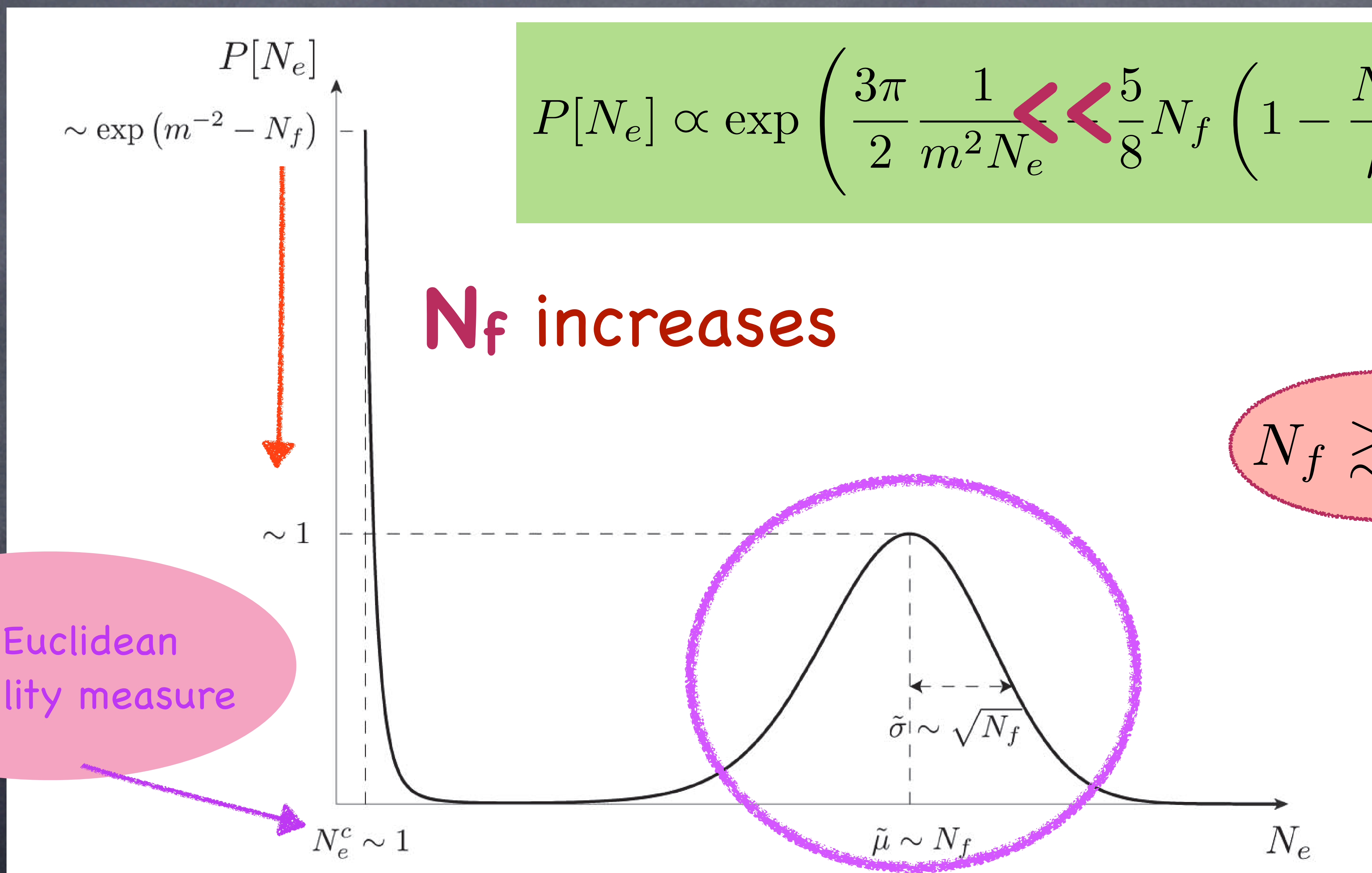


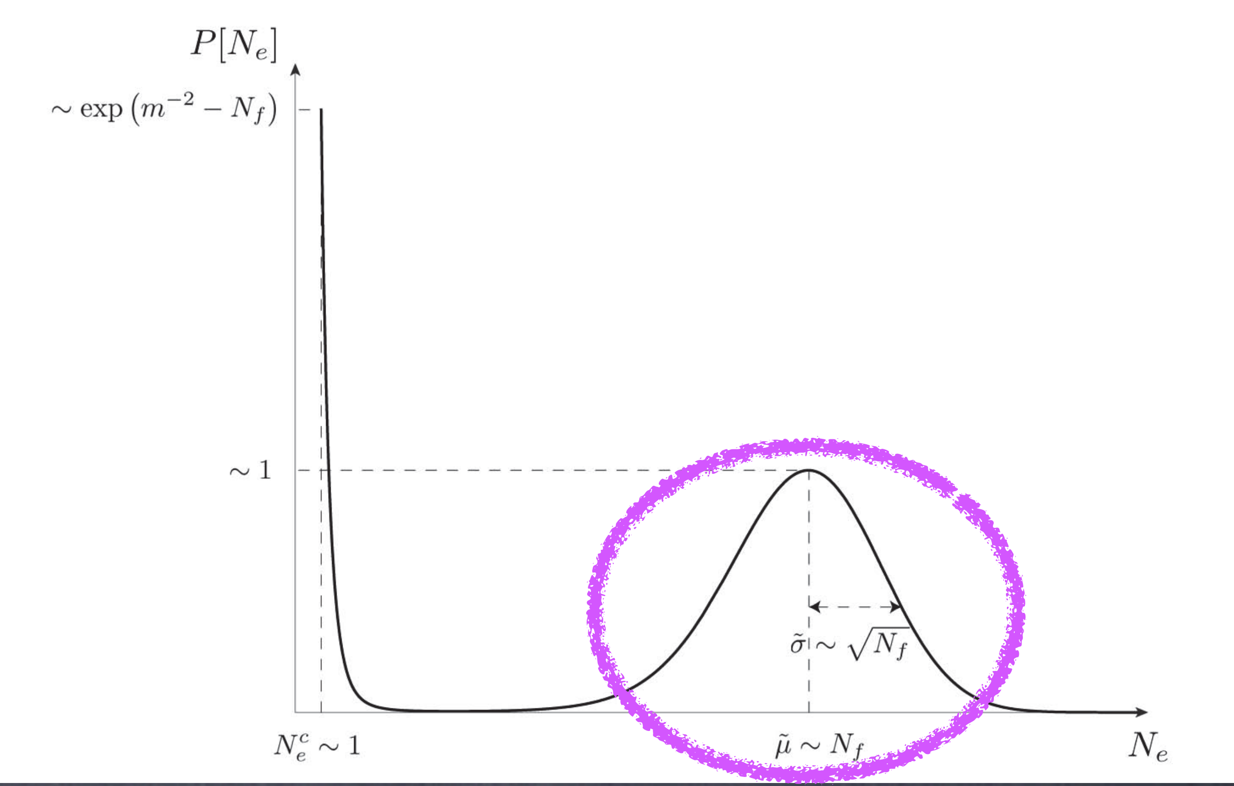
the Euclidean probability measure

N-flation phenomenology I

- The N-flation phenomenology in this approximation is remarkably simple:
  - The power spectrum
    $\mathcal{P}_{\mathcal{R}}^{1/2}$=5 x$10^{-5}$ (WMAP7)
  - normalize the scale of mass,

    $m/m_{Pl} \sim 1.3\text{x}10^{-6}$
  - The multi-field factor works for $N_f > 10^{12}$.

$$N_f \gtrsim m^{-2}$$

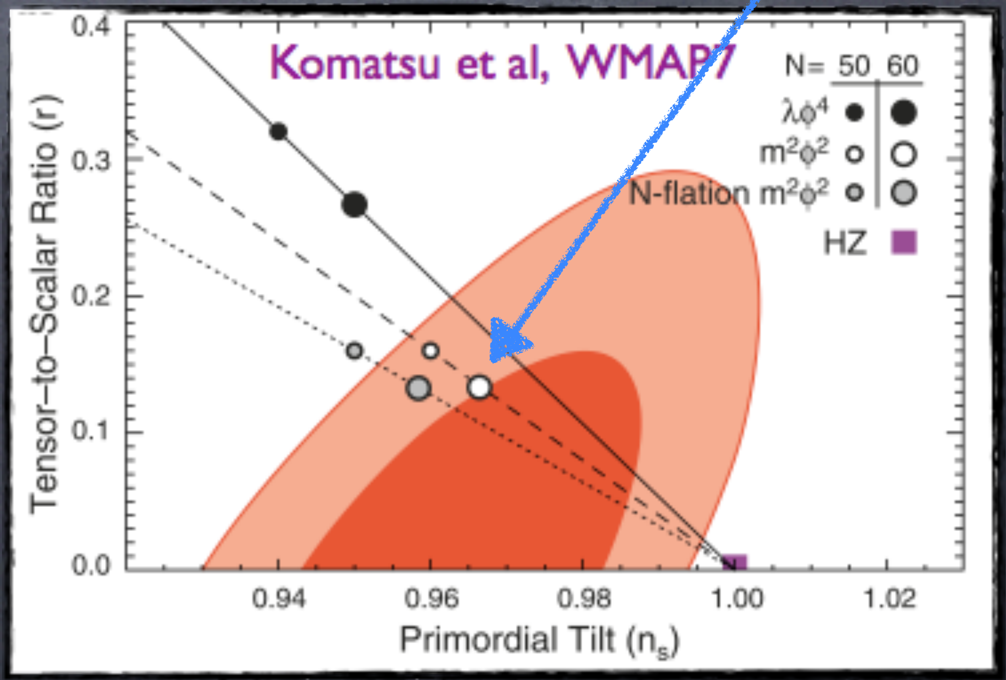


N-flation phenomenology II

- The N-flation phenomenology in this approximation is remarkably simple:
  - The tensor-to-scalar ratio always equals to the single-field values: $r = 8/N^*$ where N^* is the number of e-foldings at horizon crossing.
  - The scalar spectral index is equal to the one in the single-field value:

$$n = 1-2/N^*.$$

  - The non-gaussianity f_{NL} always equals its single-field value: $f_{NL} = 1/2N^*$ and hence is unobservably small, O(0.01).



Conclusions

- No-boundary measure
- Planckian cutoff (N-flation)
- The large number of fields can enhance the inflationary histories without adding artificial factors when $N_f > m^{-2}$ ~O(10^{12}).
  - This solves the problems that the no-boundary measure does not prefer inflationary histories